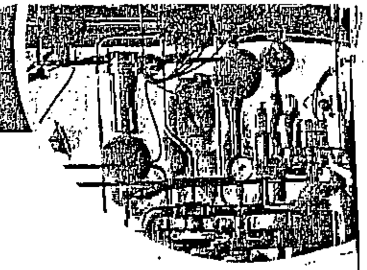
1.1 What Is Science?



Reading Focus

Key Concepts

- How does the process of science start and end?
- What is the relationship between science and technology?
- What are the branches of natural science?

Vocabulary

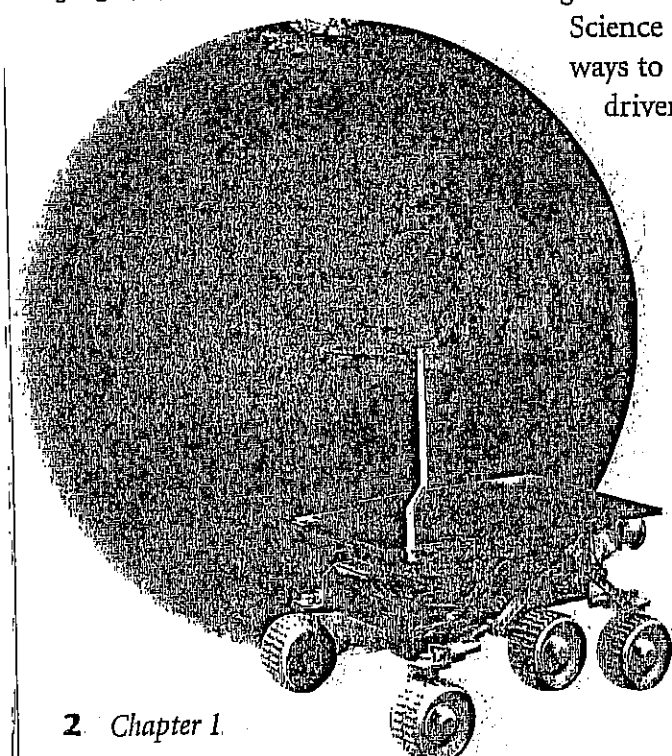
- science
- technology
- chemistry
- physics
- geology
- astronomy
- biology

Reading Strategy

Previewing Skim the section to find out what the main branches of natural science are. Copy the concept map below. As you read, complete the concept map based on what you have learned.

Natural Science
- Physical → c. ___?___
- a. ___?___ → d. ___?___
- b. ___?___ → The study of living things

Figure 1 In July 1997, the six-wheeled Sojourner rover became the first robot to explore planet Mars. The next generation of Mars rovers will help scientists further study the planet's geology, geography, and climate.



Suppose you could send a robot to another planet. What kinds of experiments would you program the robot to carry out? Before you programmed the robot, you would need to figure out what information you wanted it to gather. Scientists are currently developing robots, like the one in Figure 1, that they plan to send to Mars. These robots are being designed to examine the atmosphere, rocks, gravity, and magnetic fields of the planet.

Science involves asking questions about nature and then finding ways to answer them. This process doesn't happen by itself—it is driven by the curiosity of scientists.

Science From Curiosity

Throughout history, human beings have had a strong sense of curiosity. Human curiosity led to the use of fire, the building of tools, and the development of languages. Have you ever checked what was living at the bottom of a pond? Taken off the cover of a baseball to see what was inside? Tried putting more chocolate or less in your milk to find out how much would give the best flavor? These are all examples of curiosity, and curiosity is the basis of science.

Science is a system of knowledge and the methods you use to find that knowledge. Part of the excitement of science is that you never know what you will find. For instance, when you flip over a rock, will you see crawling insects, a snake, or nothing at all? You won't know until you look. **Science begins with curiosity and often ends with discovery.**

Curiosity provides questions but is seldom enough to achieve scientific results. Methods such as observing and measuring provide ways to find the answers. In some experiments, observations are qualitative, or descriptive. In others, they are quantitative, or numerical. Some experiments are impossible to do, such as observing what happened at the start of the universe. Scientists cannot go back in time to observe the creation of the universe. However, they can use the evidence of the universe around them to envision how this event occurred.

Reading Checkpoint *What is science?*

Science and Technology

As scientific knowledge is discovered, it can be applied in ways that improve the lives of people. **Technology** is the use of knowledge to solve practical problems. While the goal of science is to expand knowledge, the goal of technology is to apply that knowledge. Imagine living in the late 1700s, when there were no televisions, cars, antibiotics, or electricity. In a relatively small amount of time, people's lives changed dramatically. Perhaps your grandparents were born at a time when there were no televisions, and your parents were born at a time when there were no personal computers. Technology will have also changed your world dramatically by the time the generation following yours comes along.

Figure 2 illustrates the rapid evolution of the telephone, a technology invented in 1876. Within two years, the first telephone operators were connecting calls by hand. The first coin-operated phones appeared in 1889. By 1927, it was possible to make a phone call from New York to London. World War II saw the development of the first mobile telephones, which paved the way for modern cellular phones. Today, you can communicate by telephone between almost any two places in the world.

Science and technology are interdependent. Advances in one lead to advances in the other. For example, advances in the study of physics led to the invention of the transistor. The use of transistors, in turn, led to advances in various other scientific fields, such as computer science and space science.

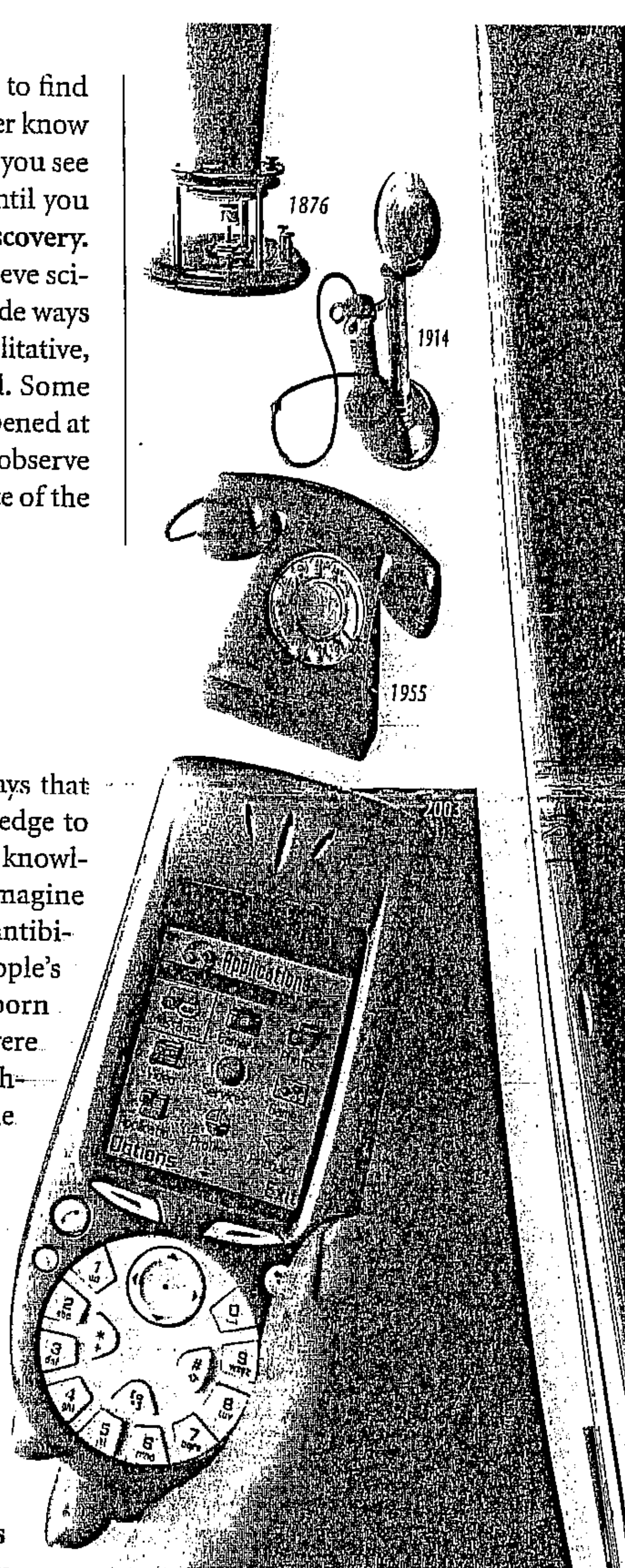


Figure 2 Telephones have quickly evolved from cumbersome, expensive machines to practical, cheap tools for communicating. **Classifying** ***How is a telephone an example of both science and technology?***

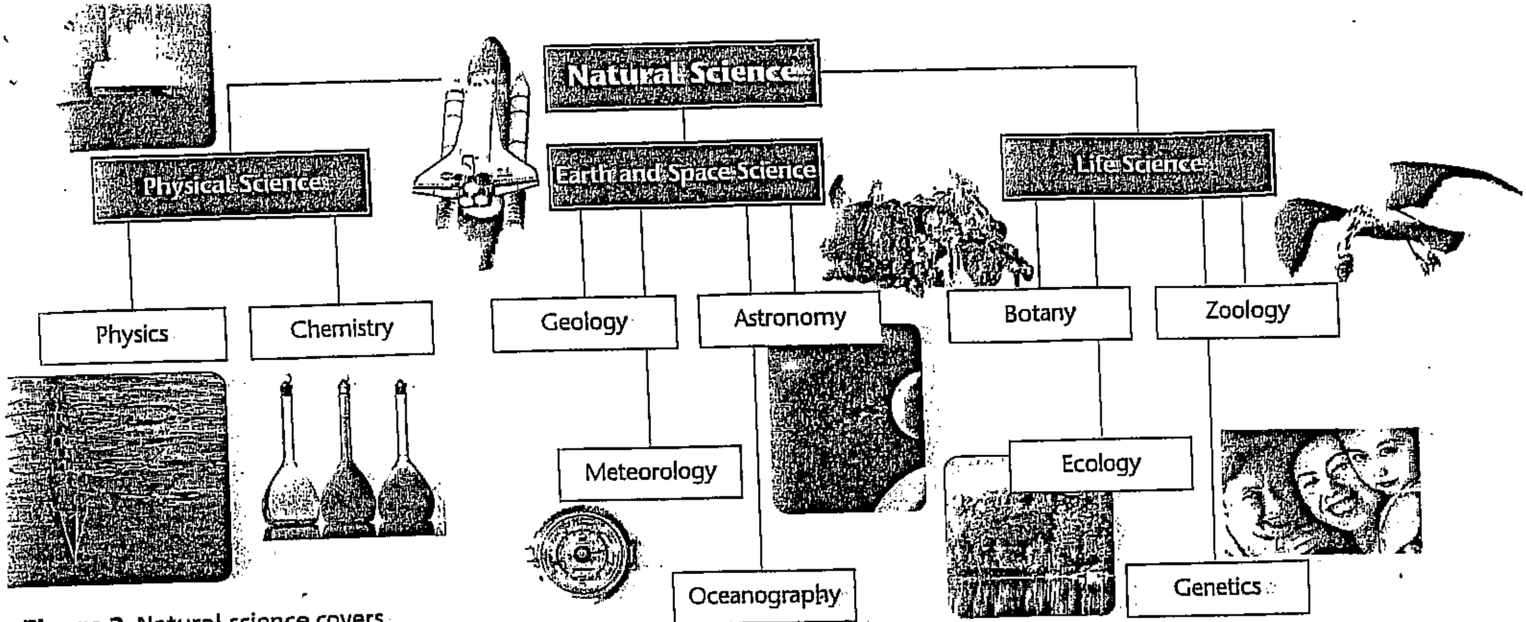


Figure 3 Natural science covers a very broad range of knowledge. **Interpreting Diagrams** ***How could you change this diagram to show how the branches of science can overlap?***

Branches of Science

The study of science is divided into social science and natural science. **Natural science is generally divided into three branches: physical science, Earth and space science, and life science.** Each of these branches can be further divided, as shown in Figure 3.

Physical science covers a broad range of study that focuses on nonliving things. The two main areas of physical science are chemistry and physics. **Chemistry** is the study of the composition, structure, properties, and reactions of matter. **Physics** is the study of matter and energy and the interactions between the two through forces and motion.

The application of physics and chemistry to the study of Earth is called Earth science. The foundation of Earth science is **geology**, the study of the origin, history, and structure of Earth. Geology has traditionally focused on the study of Earth's rocks. However, modern Earth science also involves the study of systems that may include living organisms. The foundation of space science is **astronomy**, the study of the universe beyond Earth, including the sun, moon, planets, and stars.

The study of living things is known as **biology**, or life science. Biology is not only the physics and chemistry of living things, but the study of the origin and behavior of living things. Biologists study the different ways that organisms grow, survive, and reproduce.

The problem with subdividing science into different areas is that there is often overlap between them. The boundary around each area of science is not always clear. For instance, much of biology is also chemistry, while much of chemistry is also physics. And a rapidly growing area of physics is biophysics, the application of physics to biology.

Reading Checkpoint *What is physical science?*

The Big Ideas of Physical Science

What are the basic rules of nature? You can read this book to find out. As a sneak preview, some of these rules are summarized here. You can think of them as the big ideas of physical science. Keep in mind that there are also unknown rules of nature that are waiting to be discovered. In fact, you can take part in the search for these unknown laws if you become a scientist. Even though scientists have already discovered a great deal about the universe, there is still much to learn.

Space and Time The universe is both very old and very big. The age of the universe is about 13,700,000,000 (13.7 billion) years. The observable universe is about 700,000,000,000,000,000,000,000,000 (700 million billion billion) meters in diameter. The diameter of Earth is "only" 12,700,000 meters. To get an idea of how big this distance is, the diameter of a giant beach ball is about 1 meter.

Matter and Change A very small amount of the universe is matter. Matter has volume and mass, and on Earth usually takes the form of a solid, liquid, or gas. All matter that you are familiar with, from plants to stars to animals to humans, is made up of building blocks called atoms. Atoms consist of even smaller building blocks called electrons, protons, and neutrons.

#12 **Forces and Motion** If you push on something that is sitting still, it starts to move. If you push on something that is already moving, you will change its motion. Forces cause changes in motion. As Figure 4 shows, your world is filled with motion and forces. Calculating these forces can sometimes be very challenging. For example, on a NASA mission to Mars, the Mars Exploration Rover must blast off from Earth with enough speed to escape Earth's gravity. The rocket must then travel a great distance through space and land delicately on a planet that is moving very rapidly around the Sun. The laws of physics allow these movements to be calculated exactly so that the NASA robots get to where scientists want them to go.

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Figure 4 The motion of cars on a city street is captured in this time-exposure photograph. Forces govern changes in the motion of each car.

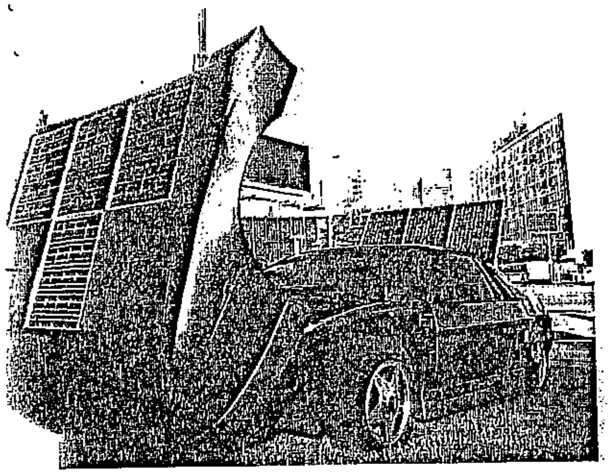


Figure 5 Panels on a solar car convert energy from the sun into the mechanical energy of its moving parts.

Energy Energy exists in many forms. Moving objects have a kind of energy called kinetic energy. Objects moved against a force have another kind of energy called potential energy. Energy also exists in matter itself. When one form of matter changes into another form, energy is either absorbed or released. Matter itself can also be changed into energy.

Energy can be transferred from one form or object to another, but it can never be destroyed. If you push on a door and it swings open, you transfer energy from yourself to the door. Your cells are using the chemical energy stored in the food you have eaten to supply energy to your muscles, which then transfer energy to the door.

Science and Your Perspective

As you read this book, remember that science is both a process and a body of knowledge. The information in this book represents the best up-to-date models of how the universe works. However, like all models, some of these models will be rejected and replaced in the future. For instance, more moons revolving around Jupiter and Saturn will most likely be discovered as telescopes get better. It is therefore possible that by the time you read this book Saturn will be known to have more than the 30 moons currently identified. Be skeptical. Ask questions. Be aware that the scientific facts of today might change tomorrow. However, believe in the scientific process that has discovered them. And believe that you may be the one who makes the discoveries that will change scientific facts in the future.

Section 1.1 Assessment

Reviewing Concepts

1. How does the scientific process start and end?
2. How are science and technology related?
3. What are the branches of natural science?
4. Explain the advantages and disadvantages of subdividing science into many different areas.
5. Why do scientists seek to discover new laws of the universe?

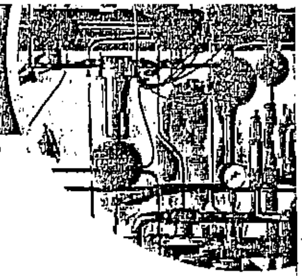
Critical Thinking

6. **Evaluating** Why does the progress of science require both curiosity and methodology? Explain the role of each in scientific investigations.
7. **Making Judgments** Advances in science do not always immediately lead to advances in technology. Why are such scientific advances still valuable?
8. **Classifying** Is the study of the muscle movements in the human body an example of biology or of physics? Explain.

Writing in Science

Compare and Contrast Paragraph Write a paragraph comparing two branches of science. (*Hint:* Use an example that shows how these branches can overlap.)

1.2 Using a Scientific Approach



Reading Focus

Key Concepts

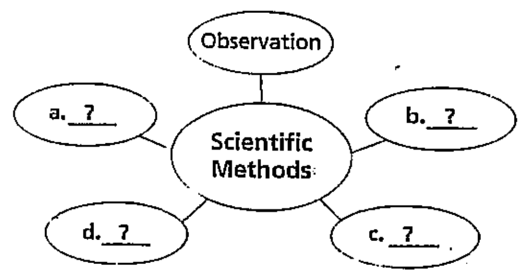
- What is the goal of a scientific method?
- How does a scientific law differ from a scientific theory?
- Why are scientific models useful?

Vocabulary

- scientific method
- observation
- hypothesis
- manipulated variable
- responding variable
- controlled experiment
- scientific theory
- scientific law
- model

Reading Strategy

Using Prior Knowledge Before you read, copy the web diagram below. Add to the web diagram what you already know about scientific methods. After you read this section, revise the diagram based on what you have learned.



If you've ever been caught in the rain without an umbrella, your first instinct was probably to start running. After all, the less time you spend in the rain, the less water there is falling down on you. So you might think that running in the rain keeps you drier than walking in the rain over a given distance. However, by running in the rain you run into more raindrops than by walking, thereby wetting more of your face, chest, and legs. Have your instincts been getting you wetter instead of keeping you drier?

You now have a question that you can try to answer with a scientific approach. Which keeps you drier in the rain—walking or running?

#13 Scientific Methods

In order to answer questions about the world around them, scientists need to get information. An organized plan for gathering, organizing, and communicating information is called a **scientific method**. Despite the name, a scientific method can be used by anyone, including yourself. All you need is a reason to use it. **The goal of any scientific method is to solve a problem or to better understand an observed event.**

Figure 6 This cricket player is running in the rain. **Designing Experiments** *How can you test if running in the rain keeps you drier than walking in the rain over the same distance?*

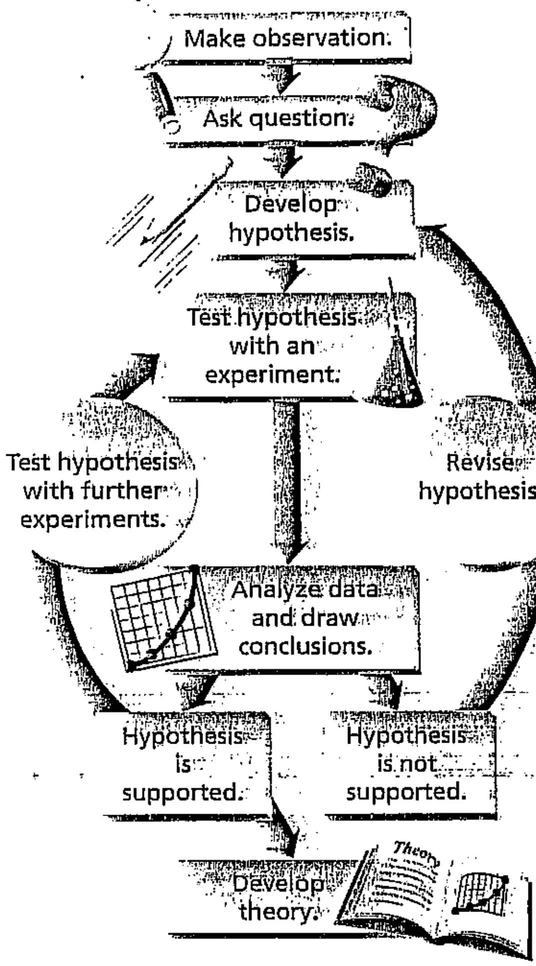


Figure 7 A scientific method provides a useful strategy for solving problems.
Inferring ***Is an observation required in order for you to arrive at a question? What does this tell you about the strictness of the scientific method?***

Figure 7 outlines an example of a scientific method. Each step in the method shown involves specific skills, some of which you will be learning as you read this book. It is important to note that scientific methods can vary from case to case. For example, one scientist might follow the steps shown in Figure 7 in a different order, or another might choose to skip one or more steps.

Making Observations Scientific investigations often begin with observations. An **observation** is information that you obtain through your senses. Repeatable observations are known as facts. For example, when you walk or run in the rain, you get wet. Standing in the rain leaves you much wetter than walking or running in the rain. You might combine these observations into a question: How does your speed affect how wet you get when you are caught in the rain?

Forming a Hypothesis A **hypothesis** is a proposed answer to a question. To answer the question raised by your observations about traveling in the rain, you might guess that the faster your speed, the drier you will stay in the rain. What can you do with your hypothesis? For a hypothesis to be useful, it must be testable.

Reading Checkpoint *What is a hypothesis?*

Testing a Hypothesis Scientists perform experiments to test their hypotheses. In an experiment, any factor that can change is called a variable. Suppose you do an experiment to test if speed affects how wet you get in the rain. The variables will include your speed, your size, the rate of rainfall, and the amount of water that hits you.

Your hypothesis states that one variable, speed, causes a change in another variable, the amount of water that hits you. The speed with which you walk or run is the **manipulated variable,** or the variable that causes a change in another. The amount of water that you accumulate is the **responding variable,** or the variable that changes in response to the manipulated variable. To examine the relationship between a manipulated variable and a responding variable, scientists use controlled experiments. A **controlled experiment** is an experiment in which only one variable, the manipulated variable, is deliberately changed at a time. While the responding variable is observed for changes, all other variables are kept constant, or controlled.

In 1997, two meteorologists conducted a controlled experiment to determine if moving faster keeps you drier in the rain. In the experiment, both scientists traveled 100 yards by foot in the rain. One of them walked; the other ran. By measuring the mass of their clothes before and after traveling in the rain, the scientists were able to measure how much water each had accumulated. One of the controlled variables was size—the two scientists were about the same height and build. Another was the rate of rainfall—the scientists began traveling at the same time during the same rainstorm on the same path. A third was the ability to absorb water—the scientists wore identical sets of clothes.

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Drawing Conclusions The scientists' rainy-day experiment produced some convincing data. The clothes of the walking scientist accumulated 217 grams of water, while the clothes of the running scientists accumulated 130 grams of water. Based on their data, the scientists concluded that running in the rain keeps you drier than walking—about 40 percent drier, in fact. Now you have scientific evidence to support the hypothesis stated earlier.

What happens if the data do not support the hypothesis? In such a case, a scientist can revise the hypothesis or propose a new one, based on the data from the experiment. A new experiment must then be designed to test the revised or new hypothesis.

Developing a Theory Once a hypothesis has been supported in repeated experiments, scientists can begin to develop a theory. A **scientific theory** is a well-tested explanation for a set of observations or experimental results. For example, according to the kinetic theory of matter, all particles of matter are in constant motion. Kinetic theory explains a wide range of observations, such as ice melting or the pressure of a gas.

Theories are never proved. Instead, they become stronger if the facts continue to support them. However, if an existing theory fails to explain new facts and discoveries, the theory may be revised or a new theory may replace it.

Figure 8 An environmental scientist collects a sample for a water pollution study. After analyzing the sample, the scientist can draw conclusions about how the water became polluted.

Scientific Laws

After repeated observations or experiments, scientists may arrive at a scientific law. A **scientific law** is a statement that summarizes a pattern found in nature. For example, Newton's law of gravity describes how two objects attract each other by means of a gravitational force. This law has been verified over and over. However, scientists have yet to agree on a theory that explains how gravity works. **A scientific law describes an observed pattern in nature without attempting to explain it. The explanation of such a pattern is provided by a scientific theory.**

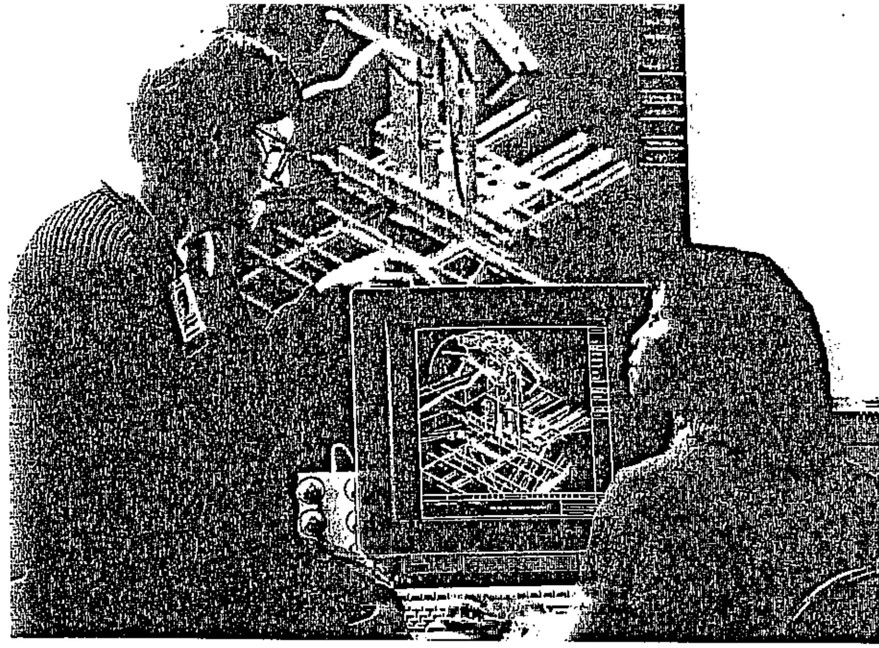


Figure 9 Two engineers discuss a computer-aided design, or CAD, of an aircraft component.

Scientific Models

If you have ever been lost in a city, you know that a street map can help you find your location. A street map is a type of **model**, or representation, of an object or event. **Scientific models make it easier to understand things that might be too difficult to observe directly.** For example, to understand how Earth rotates on its axis, you could look at a globe, which is a small-scale model of Earth. The computer model in Figure 9 represents the interior of an airplane. Other models help you visualize things that are too small to see, such as atoms. As long as a model lets you mentally picture what is supposed to be represented, then the model has done its job.

An example of a mental, rather than physical, model might be that comets are like giant snowballs, primarily made of ice. Scientists would test this model through observations, experiments, and calculations. Possibly they would even send a space probe—a visit to a comet really is planned! If all of these tests support the idea that comets are made of ice, then the model of icy comets will continue to be believed.

However, if the data show that this model is wrong, then it must either be changed or be replaced by a new model. If scientists never challenged old models, then nothing new would be learned, and we would still believe what we believed hundreds of years ago. Science works by making mistakes. The fact that newer models are continually replacing old models is a sign that new discoveries are continually occurring. As the knowledge that makes up science keeps changing, scientists develop a better and better understanding of the universe.

Reading Checkpoint *What is a model?*

Working Safely in Science

Scientists working in the field, or in a laboratory, like those in Figure 10, are trained to use safe procedures when carrying out investigations. Laboratory work may involve flames or hot plates, electricity, chemicals, hot liquids, sharp instruments, and breakable glassware.

Whenever you work in your science laboratory, it's important for you to follow safety precautions at all times. Before performing any activity in this course, study the rules in the Science Safety section of the Skills Handbook. Before you start any activity, read all the steps. Make sure that you understand the entire procedure, especially any safety precautions that must be followed.

Figure 10 Safety plays an important role in science. **Interpreting Photos** *What safety measures are these scientists taking in their laboratory work?*

The single most important rule for your safety is simple: Always follow your teacher's instructions and the textbook directions exactly. If you are in doubt about any step in an activity, always ask your teacher for an explanation. Because you may be in contact with chemicals you cannot see, it is essential that you wash your hands thoroughly after every scientific activity. Remember, you share responsibility for your own safety and that of your teacher and classmates.

Section 1.2 Assessment

Reviewing Concepts

1. What is the goal of scientific methods?
2. How does a scientific law differ from a scientific theory?
3. Why are scientific models useful?
4. What are three types of variables in a controlled experiment?
5. Does every scientific method begin with an observation? Explain.

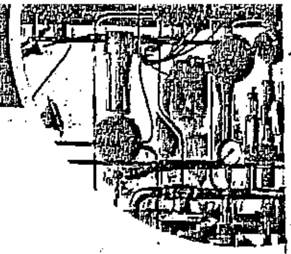
Critical Thinking

6. **Classifying** The scientists who tested the hypothesis on running in the rain performed only one controlled experiment that supported their hypothesis. Can their supported hypothesis be called a theory? Explain.
7. **Designing Experiments** Suppose you wanted to find out how running affects your pulse rate. What would your hypothesis be? Explain how you could test your hypothesis.
8. **Using Models** A scientific model can take the form of a physical object or a concept. List one example of each type of model. How does each one resemble what it is supposed to model?

Writing in Science

Descriptive Paragraph Write a paragraph describing the steps of a scientific method. (*Hint:* Before you write, use a flowchart to arrange your steps in a particular order.)

1.3 Measurement



Reading Focus

Key Concepts

- Why is scientific notation useful?
- What units do scientists use for their measurements?
- How does the precision of measurements affect the precision of scientific calculations?

Vocabulary

- scientific notation
- length
- mass
- volume
- density
- conversion factor
- precision
- significant figures
- accuracy
- thermometer

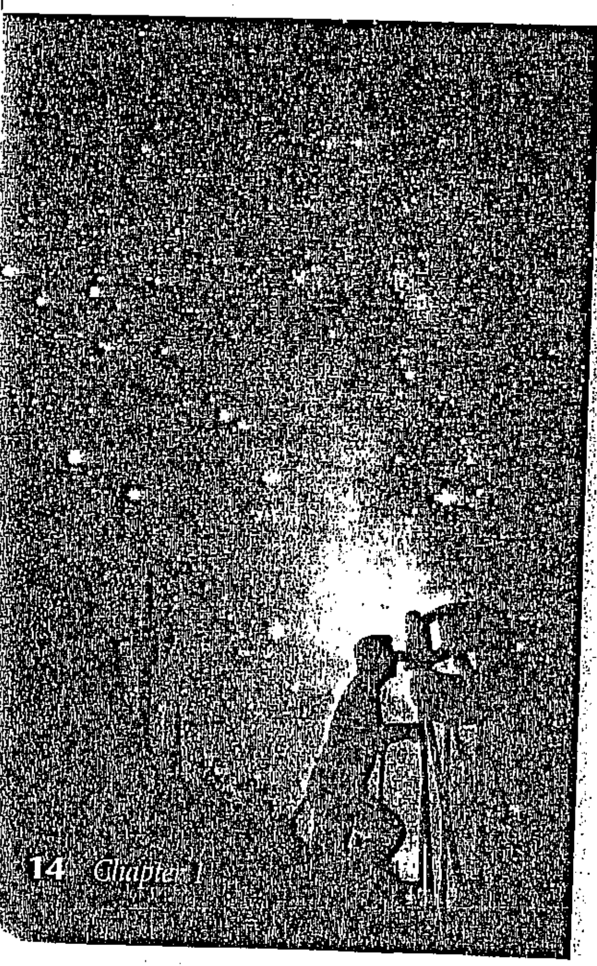
Reading Strategy

Previewing Make a table like the one below. Before you read the section, rewrite the green and blue topic headings as questions. As you read, write answers to the questions.

Measurement
Why is scientific notation useful?
a. ___?___
b. ___?___

How old are you? How tall are you? The answers to these questions are measurements. Measurements are important in both science and everyday life. Hardly a day passes without the need for you to measure amounts of money or the passage of time. It would be difficult to imagine doing science without any measurements.

Figure 11 Scientists estimate that there are more than 200 billion stars in the Milky Way galaxy. **Applying Concepts** *What is this number in scientific notation?*



Using Scientific Notation

How many stars do you see in Figure 11? There are too many to count. Scientists often work with very large or very small numbers. For example, the speed of light is about 300,000,000 meters per second. On the other hand, an average snail has been clocked at a speed of only 0.00086 meter per second.

Instead of having to write out all the zeroes in these numbers, you can use a shortcut called scientific notation. **Scientific notation** is a way of expressing a value as the product of a number between 1 and 10 and a power of 10. For example, the number 300,000,000 written in scientific notation is 3.0×10^8. The exponent, 8, tells you that the decimal point is really 8 places to the right of the 3.

For numbers less than 1 that are written in scientific notation, the exponent is negative. For example, the number 0.00086 written in scientific notation is 8.6×10^{-4}. The negative exponent tells you how many decimals places there are to the *left* of the 8.6. **Scientific notation makes very large or very small numbers easier to work with.**

When multiplying numbers written in scientific notation, you multiply the numbers that appear before the multiplication signs and *add* the exponents. For example, to calculate how far light travels in 500 seconds, you multiply the speed of light by the number of seconds.

$$(3.0 \times 10^8 \text{ m/s}) \times (5.0 \times 10^2 \text{ s}) = 15 \times 10^{10} \text{ m} = 1.5 \times 10^{11} \text{ m}$$

This distance is about how far the sun is from Earth.

When dividing numbers written in scientific notation, you divide the numbers that appear before the exponential terms and *subtract* the exponents. For example, to calculate how long it takes for light from the sun to reach Earth, you would perform a division.

$$\frac{1.5 \times 10^{11} \text{ m}}{3.0 \times 10^8 \text{ m/s}} = \frac{1.5}{3.0} \times 10^{11-8} \text{ s} = 0.50 \times 10^3 \text{ s} = 5.0 \times 10^2 \text{ s}$$

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Math Skills

Using Scientific Notation

A rectangular parking lot has a length of 1.1×10^3 meters and a width of 2.4×10^3 meters. What is the area of the parking lot?

1 Read and Understand

What information are you given?

Length $(l) = 1.1 \times 10^3$ m

Width $(w) = 2.4 \times 10^3$ m

2 Plan and Solve

What unknown are you trying to calculate?

Area $(A) = ?$

What formula contains the given quantities and the unknown?

$$A = l \times w$$

Replace each variable with its known value.

$$A = l \times w = (1.1 \times 10^3 \text{ m})(2.4 \times 10^3 \text{ m})$$
$$= (1.1 \times 2.4)(10^{3+3})(\text{m} \times \text{m})$$
$$= 2.6 \times 10^6 \text{ m}^2$$

3 Look Back and Check

Is your answer reasonable?

Yes, the number calculated is the product of the numbers given, and the units (m^2) indicate area.

Math Practice

1. Perform the following calculations. Express your answers in scientific notation.
   a. $(7.6 \times 10^{-4} \text{ m}) \times (1.5 \times 10^7 \text{ m})$
   b. $0.00053 \div 29$
2. Calculate how far light travels in 8.64×10^4 seconds. (*Hint:* The speed of light is about 3.0×10^8 m/s.)

Figure 12 A measurement consists of a number and a unit. One of the units used to measure temperature is the degree Celsius.

SI Units of Measurement

For a measurement to make sense, it requires both a number and a unit. For example, if you told one of your friends that you had finished a homework assignment "in five," what would your friend think? Would it be five minutes or five hours? Maybe it was a long assignment, and you actually meant five days. Or maybe you meant that you wrote five pages. You should always express measurements in numbers and units so that their meaning is clear. In Figure 12, students are measuring temperature in degrees Celsius.

Many of the units you are familiar with, such as inches, feet, and degrees Fahrenheit, are not units that are used in science. **Scientists use a set of measuring units called SI, or the International System of Units.** The abbreviation stands for the French name *Système International d'Unités.* SI is a revised version of the metric system, which was originally developed in France in 1791. By adhering to one system of units, scientists can readily interpret one another's measurements.

Base Units and Derived Units SI is built upon seven metric units, known as base units, which are listed in Figure 13. In SI, the base unit for **length**, or the straight-line distance between two points, is the meter (m). The base unit for **mass**, or the quantity of matter in an object or sample, is the kilogram (kg).

Additional SI units, called derived units, are made from combinations of base units. Figure 14 lists some common derived units. For example, **volume** is the amount of space taken up by an object. The volume of a rectangular box equals its length times its width times its height. Each of these dimensions can be measured in meters, so you can derive the SI unit for volume by multiplying meters by meters by meters, which gives you cubic meters (m^3).

SI Base Units

Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Temperature	kelvin	K
Time	second	s
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

Figure 13 Seven metric base units make up the foundation of SI.

Derived Units

Quantity	Unit	Symbol
Area	square meter	m^2
Volume	cubic meter	m^3
Density	kilograms per cubic meter	kg/m^3
Pressure	pascal ($kg/m \cdot s^2$)	Pa
Energy	joule ($kg \cdot m^2/s^2$)	J
Frequency	hertz (1/s)	Hz
Electric charge	coulomb ($A \cdot s$)	C

Figure 14 Specific combinations of SI base units yield derived units.

SI Prefixes			
Prefix	Symbol	Meaning	Multiply Unit by
giga-	G	billion (10^9)	1,000,000,000
mega-	M	million (10^6)	1,000,000
kilo-	k	thousand (10^3)	1000
deci-	d	tenth (10^{-1})	0.1
centi-	c	hundredth (10^{-2})	0.01
milli-	m	thousandth (10^{-3})	0.001
micro-	μ	millionth (10^{-6})	0.000001
nano-	n	billionth (10^{-9})	0.000000001

Figure 15 Metric prefixes allow for more convenient ways to express SI base and derived units.

Another quantity that requires a derived unit is density. **Density** is the ratio of an object's mass to its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

To derive the SI unit for density, you can divide the base unit for mass by the derived unit for volume. Dividing kilograms by cubic meters yields the SI unit for density, kilograms per cubic meter (kg/m^3).

Reading Checkpoint *What is the SI derived unit for density?*

Metric Prefixes The metric unit for a given quantity is not always a convenient one to use. For example, the time it takes for a computer hard drive to read or write data—also known as the seek time—is in the range of thousandths of a second. A typical seek time might be 0.009 second. This can be written in a more compact way by using a metric prefix. A metric prefix indicates how many times a unit should be multiplied or divided by 10. Figure 15 shows some common metric prefixes. Using the prefix *milli-* (m), you can write 0.009 second as 9 milliseconds, or 9 ms.

$$9 \text{ ms} = \frac{9}{1000} \text{ s} = 0.009 \text{ s}$$

Note that dividing by 1000 is the same as multiplying by 0.001.

Metric prefixes can also make a unit larger. For example, a distance of 12,000 meters can also be written as 12 kilometers.

$$12 \text{ km} = 12 \times 1000 \text{ m} = 12{,}000 \text{ m}$$

Metric prefixes turn up in non-metric units as well. If you work with computers, you probably know that a gigabyte of data refers to 1,000,000,000 bytes. A megapixel is 1,000,000 pixels.

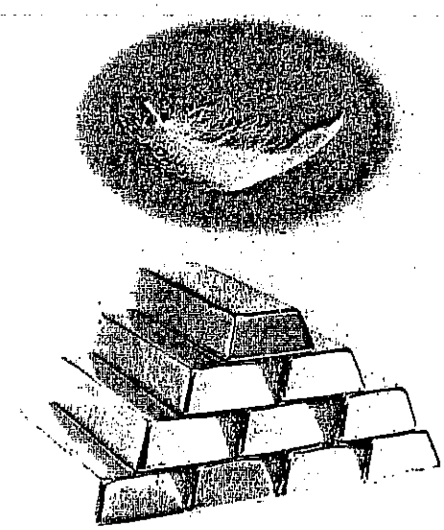


Figure 16 A bar of gold has more mass per unit volume than a feather. **Inferring** *Which takes up more space—one kilogram of gold or one kilogram of feathers?*

Nutrition Facts	
Serving Size 1 oz (28g/about 18 chips)	
Servings Per Container 7	
Amount Per Serving	
Calories 150	Calories from Fat 80
	% Daily Value*
Total Fat 9g	14%
Saturated Fat 1g	5%
Polyunsaturated Fat 1g	
Monounsaturated Fat 7g	
Cholesterol 0mg	0%
Sodium 160mg	7%

Figure 17 Nutrition labels often have some measurements listed in grams and milligrams.
Calculating *How many grams are in 160 milligrams?*

The easiest way to convert from one unit of measurement to another is to use conversion factors. A **conversion factor** is a ratio of equivalent measurements that is used to convert a quantity expressed in one unit to another unit. Suppose you want to convert the height of Mount Everest, 8848 meters, into kilometers. Based on the prefix *kilo-*, you know that 1 kilometer is 1000 meters. This ratio gives you two possible conversion factors.

$$\frac{1\text{ km}}{1000\text{ m}} \qquad \frac{1000\text{ m}}{1\text{ km}}$$

Since you are converting from meters to kilometers, the number should get smaller. Multiplying by the conversion factor on the left yields a smaller number.

$$8848\ \cancel{\text{m}} \times \frac{1\text{ km}}{1000\ \cancel{\text{m}}} = 8.848\text{ km}$$

Notice that the meter units cancel, leaving you with kilometers (the larger unit).

To convert 8.848 kilometers back into meters, multiply by the conversion factor on the right. Since you are converting from kilometers to meters, the number should get larger.

$$8.848\ \cancel{\text{km}} \times \frac{1000\text{ m}}{1\ \cancel{\text{km}}} = 8848\text{ m}$$

In this case, the kilometer units cancel, leaving you with meters.

Quick Lab

Comparing Precision

Materials

3 plastic bottles of different sizes, beaker, graduated cylinder

Procedure

1. Draw a data table with three rows and three columns. Label the columns Estimate, Beaker, and Graduated Cylinder.
2. Record your estimate of the volume of a plastic bottle in your data table. Then, fill the bottle with water and pour the water into the beaker. Read and record the volume of the water.
3. Pour the water from the beaker into the graduated cylinder. Read and record the volume of water.
4. Repeat Steps 2 and 3 with two other plastic bottles.

Analyze and Conclude

1. **Analyzing Data** Review your volume measurements for one of the bottles. How many significant figures does the volume measured with the beaker have? How many significant figures does the volume measured with the graduated cylinder have?
2. **Comparing and Contrasting** Which provided a more precise measurement—the beaker or the graduated cylinder?
3. **Inferring** How could you determine the accuracy of your measurements?

Limits of Measurement

Suppose you wanted to measure how much time it takes for you to eat your breakfast. Figure 18 shows two clocks you could use—an analog clock and a digital clock. The analog clock displays time to the nearest minute. The digital clock displays time to the nearest second (or one sixtieth of a minute). Which clock would you choose?

Precision The digital clock offers more precision. **Precision** is a gauge of how exact a measurement is. According to the analog clock, it might take you 5 minutes to eat your breakfast. Using the digital clock, however, you might measure 5 minutes and 15 seconds, or 5.25 minutes. The second measurement has more significant figures. **Significant figures** are all the digits that are known in a measurement, plus the last digit that is estimated. The time recorded as 5.25 minutes has three significant figures. The time recorded as 5 minutes has one significant figure. The fewer the significant figures, the less precise the measurement is.

When you make calculations with measurements, the uncertainty of the separate measurements must be correctly reflected in the final result. **The precision of a calculated answer is limited by the least precise measurement used in the calculation.** So if the least precise measurement in your calculation has two significant figures, then your calculated answer can have at most two significant figures.

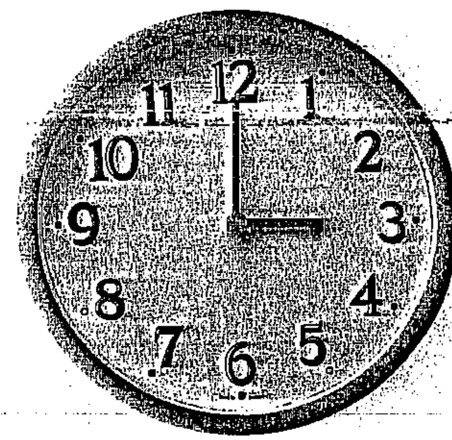
Suppose you measure the mass of a piece of iron to be 34.73 grams on an electronic balance. You then measure the volume to be 4.42 cubic centimeters. What is the density of the iron?

$$\text{Density} = \frac{34.73 \text{ g}}{4.42 \text{ cm}^3} = 7.857466 \text{ g/cm}^3$$

Your answer should have only three significant figures because the least precise measurement, the volume, has three significant figures. Rounding your answer to three significant figures gives you a density of 7.86 grams per cubic centimeter.

Accuracy Another important quality in a measurement is its accuracy. **Accuracy** is the closeness of a measurement to the actual value of what is being measured. For example, suppose the digital clock in Figure 18 is running 15 minutes slow. Although the clock would remain precise to the nearest second, the time displayed would not be accurate.

Reading Checkpoint *What is accuracy?*



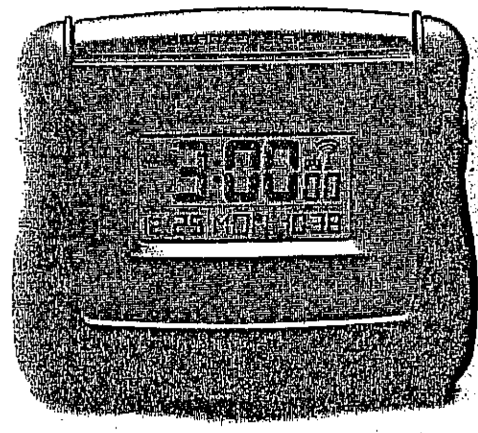


Figure 18 A more precise time can be read from the digital clock than can be read from the analog clock. The digital clock is precise to the nearest second, while the analog clock is precise to the nearest minute.

Common Temperatures	Fahrenheit (°F)	Celsius (°C)	Kelvin (K)
Water boils	212	100	373
Human body	98.6	37	310
Average room	68	20	293
Water freezes	32	0	273

Figure 19 Temperature can be expressed in degrees Fahrenheit, degrees Celsius, or kelvins.

Measuring Temperature

A thermometer is an instrument that measures temperature, or how hot an object is. The How It Works box on page 21 describes how a bulb thermometer measures temperature.

The two temperature scales that you are probably most familiar with are the Fahrenheit scale and the Celsius scale. On the Fahrenheit scale, water freezes at 32°F and boils at 212°F at sea level. On the Celsius (or centigrade) scale, water freezes at 0°C and boils at 100°C. A degree Celsius is almost twice as large as a degree Fahrenheit. There is also a difference of 32 degrees between the zero point of the Celsius scale and the zero point of the Fahrenheit scale. You can convert from one scale to the other by using one of the following formulas.

$$°C = \frac{5}{9}(°F - 32.0°) \qquad °F = \frac{9}{5}(°C) + 32.0°$$

The SI base unit for temperature is the kelvin (K). A temperature of 0 K, or 0 kelvin, refers to the lowest possible temperature that can be reached. In degrees Celsius, this temperature is −273.15°C. To convert between kelvins and degrees Celsius, use the following formula.

$$K = °C + 273$$

Figure 19 compares some common temperatures expressed in degrees Celsius, degrees Fahrenheit, and kelvins.

Section 1.3 Assessment

Reviewing Concepts

1. Why do scientists use scientific notation?
2. What system of units do scientists use for measurements?
3. How does the precision of measurements affect the precision of scientific calculations?
4. List the SI units for mass, length, and temperature.

Critical Thinking

5. **Applying Concepts** A bulb thermometer gives an indoor temperature reading of 21°C. A digital thermometer in the same room gives a reading of 20.7°C. Which device is more precise? Explain.
6. **Calculating** Convert −11°F into degrees Celsius, and then into kelvins.

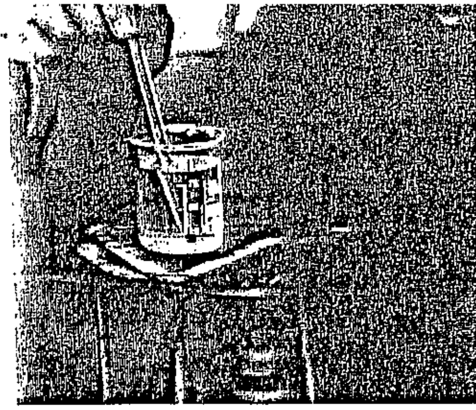
Math Practice

7. Write the following measurements in scientific notation. Then convert each measurement into SI base units.
   a. 0.0000000000372 g
   b. 45,000,000,000 km
8. The liquid in a bulb thermometer falls 1.1 cm. Calculate the liquid's change in volume if the inner radius of the tube is 6.5×10^{-3} cm.

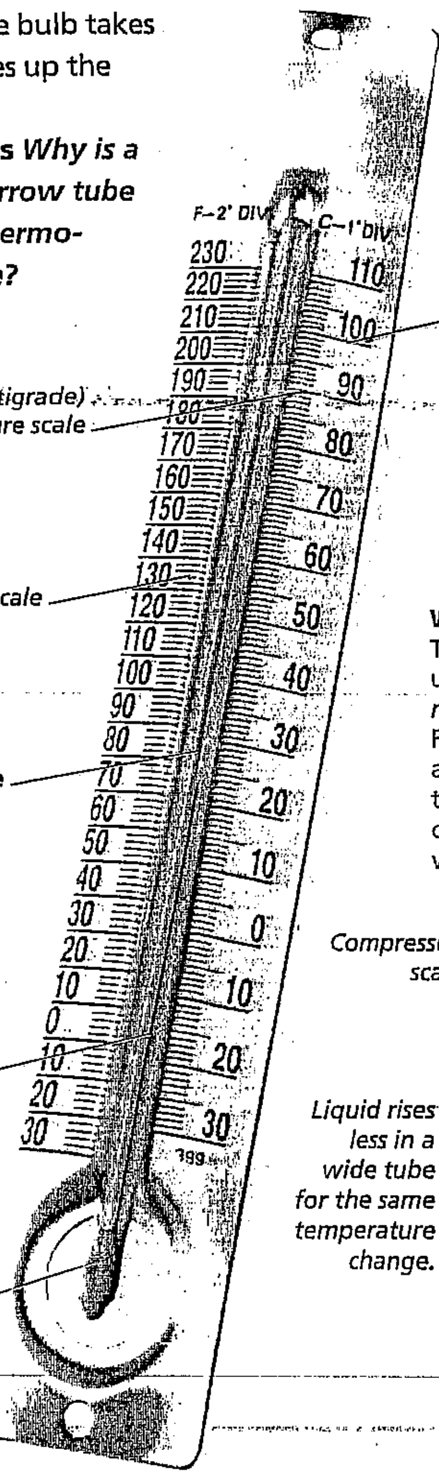
Thermometer

A bulb thermometer consists of a sealed, narrow glass tube, called a capillary tube. It has a glass bulb at one end and is filled with colored alcohol or mercury. The thermometer works on the principle that the volume of a liquid changes when the temperature changes. When warmed, the liquid in the bulb takes up more space and moves up the capillary tube.

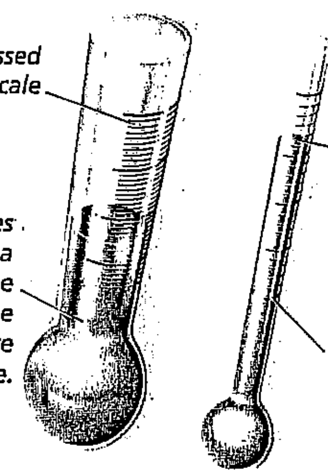
Interpreting Diagrams ***Why is a thermometer with a narrow tube easier to read than a thermometer with a wide tube?***



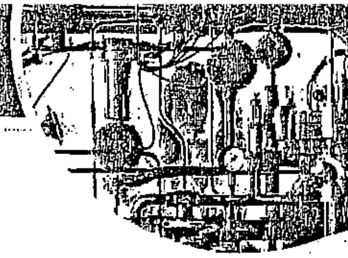
Measuring temperature Thermometers are useful scientific instruments. They can be used to measure the static temperature of a material, or to record the change in temperature of a substance being heated, as shown above.



Wide or narrow?
The volume of a tube is calculated using the formula $V = \pi r^2 l$, where r is the radius and l is the length. For a given volume, if the radius of a tube is decreased (as in a capillary tube), the length of the liquid column increases. Any change in volume is then easier to see.



1.4 Presenting Scientific Data



Reading Focus

Key Concepts

- How do scientists organize data?
- How can scientists communicate experimental data?

Vocabulary

- slope
- direct proportion
- inverse proportion

Reading Strategy

Comparing and Contrasting After you read this section, compare types of graphs by completing the table below.

Type of Graph	Description	Used For
Line	a. ___?___	b. ___?___
Bar	c. ___?___	d. ___?___
Circle	e. ___?___	f. ___?___

Much of the information you get every day comes from the news media. Newspapers, television, radio, and the Internet let you access a wealth of information about events going on in the world. But in order for news to be useful, it must be communicated. If a news reporter witnesses an event but doesn't report it, then he might as well not have seen it. If the event is reported, then it must be described in a clear, organized manner for it to be understood and appreciated. Like the news, scientific data become meaningful only when they are organized and communicated.

Average Annual Precipitation for Selected U.S. Cities

City	Average Annual Precipitation (cm)
Buffalo, N.Y.	98.0
Chicago, Ill.	91.0
Colorado Springs, Colo.	41.2
Houston, Tex.	117.0
San Diego, Calif.	25.1
Tallahassee, Fla.	166.9
Tucson, Ariz.	30.5

Figure 20 Using a table is a simple way to present data visually.

Organizing Data

Scientists accumulate vast amounts of data by observing events and making measurements. Interpreting these data can be a difficult task if they are not organized. **Scientists can organize their data by using data tables and graphs.** These tools make it easier to spot patterns or trends in the data that can support or disprove a hypothesis.

Data Tables The simplest way to organize data is to present them in a table. Figure 20 is a data table that shows the average annual precipitation for seven U.S. cities. The table relates two variables—a manipulated variable (location) and a responding variable (average annual precipitation).

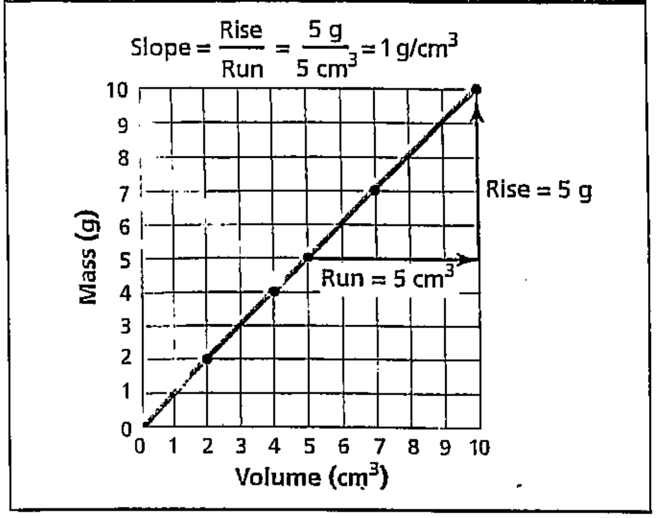


Figure 21 Plotting the mass of water against the volume of water yields a straight line.
Using Graphs ***What does the slope represent?***

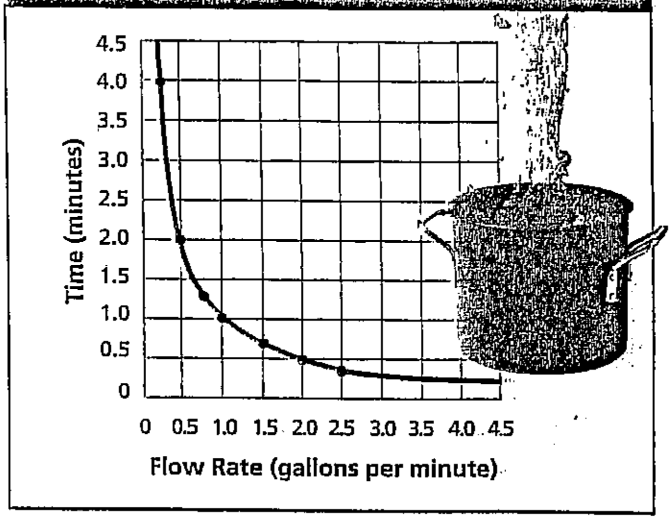


Figure 22 In an inverse proportion, the product of two variables remains constant. Each point on the graph above represents the same volume of water: 1 gallon.

Line Graphs A line graph is useful for showing changes that occur in related variables. In a line graph, the manipulated variable is generally plotted on the horizontal axis, or x-axis. The responding variable is plotted on the vertical axis, or y-axis, of the graph.

Figure 21 is a line graph that shows how the mass of water increases with volume. The data points yield a straight line. The steepness, or **slope**, of this line is the ratio of a vertical change to the corresponding horizontal change. The formula for the slope of a line is

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}}$$

"Rise" represents the change in the y-variable. "Run" represents the corresponding change in the x-variable. Note that in Figure 21, because mass per unit volume is density, the slope represents the density of water.

The relationship between the mass and volume of water is an example of a direct proportion. A **direct proportion** is a relationship in which the ratio of two variables is constant. For example, suppose you have a 3-cubic-centimeter sample of water that has a mass of 3 grams. Doubling the volume of the sample to 6 cubic centimeters results in doubling the mass of the sample to 6 grams. Tripling the volume to 9 cubic centimeters results in tripling the mass to 9 grams.

Figure 22 shows how the flow rate of a water faucet affects the time required to fill a 1-gallon pot. Figure 22 illustrates an **inverse proportion,** a relationship in which the product of two variables is a constant. If you start with a flow rate of 0.5 gallon per minute, you will fill the pot in 2 minutes. If you double the flow rate to 1.0 gallon per minute, you reduce the time required to fill the pot to 1 minute, or one half of the original time.

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Data Analysis

Faster Than Speeding Data

A modem is a device used to send and receive data. For example, if you upload an image to a Web site, the modem in your computer converts the data of the image into a different format. The converted data are then sent through a telephone line or cable TV line. The smallest unit of data that can be read by a computer is a binary digit, or "bit." A bit is either a 0 or a 1. Computers process bits in larger units called bytes. A byte is a group of eight bits.

The table shows the data transfer rates for modems used in home computers. Data transfer rates are often measured in kilobits per second, or kbps. The time required to upload a 1-megabyte (MB) file is given for each rate listed.

Modem Speeds

Type of Modem	Data Transfer Rate (kbps)	Upload Time for 1 MB (s)
56K dial-up	33.6	238
Cable	64	125
DSL	128	63
Cable	256	31
DSL	640	13

1. **Using Graphs** Use the data in the table to create a line graph. Describe the relationship between data transfer rate and upload time.
2. **Inferring** How would doubling the data transfer rate affect the upload time?

Bar Graphs A bar graph is often used to compare a set of measurements, amounts, or changes. Figure 23 is a bar graph of the data from Figure 20. The bar graph makes it easy to see how the data for one city compare with the data for another.

Circle Graphs If you think of a pie cut into pieces, you have a mental model of a circle graph. A circle graph is a divided circle that shows how a part or share of something relates to the whole. Figure 24 is a circle graph that describes the composition of Earth's crust. The entire circle represents the mass of Earth's crust. Each "slice" of the circle represents a percentage of that mass corresponding to a specific substance.

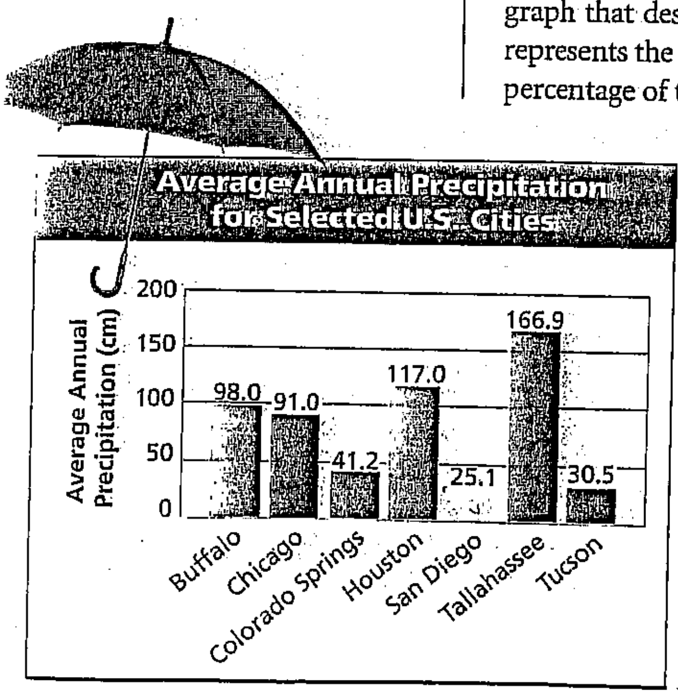


Figure 23 A bar graph is useful for comparing several measurements.

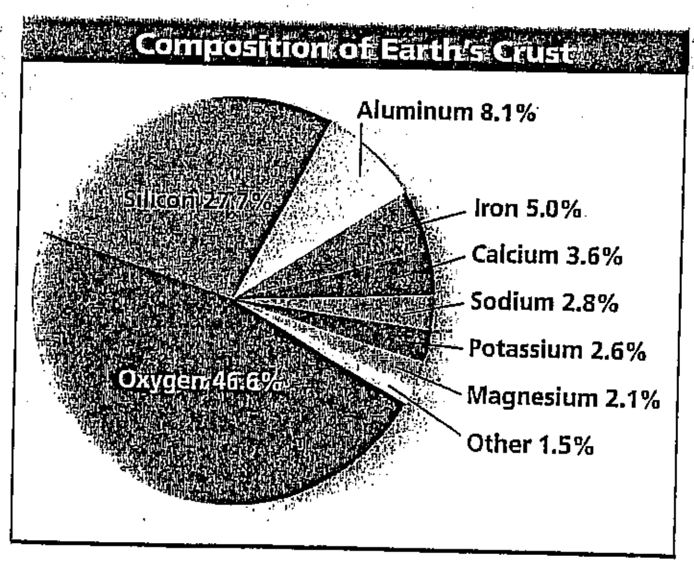
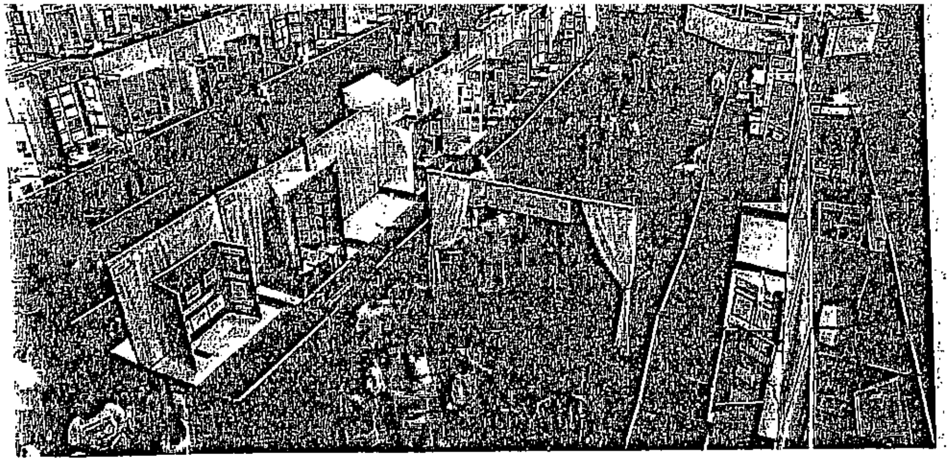


Figure 24 A circle graph is useful for showing how a part of something relates to the whole.



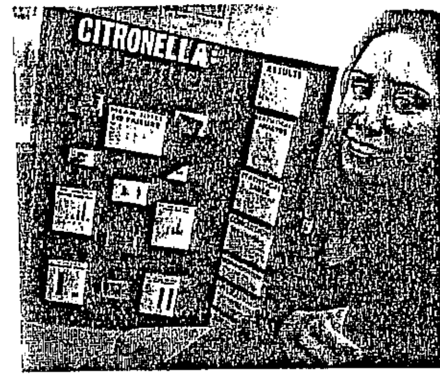


Figure 25 At a science fair, students communicate what knowledge they have gained by using scientific methods.

Communicating Data

A crucial part of any scientific investigation is reporting the results. **Scientists can communicate results by writing in scientific journals or speaking at conferences.** Scientists also exchange information through conversations, e-mails, and Web sites. Young scientists often present their research at science fairs like the one in Figure 25.

Different scientists may interpret the same data differently. This important notion is the basis for peer review, a process in which scientists examine other scientists' work. Not only do scientists share research with their peers, but they also invite feedback from those peers. Peer review encourages comments, suggestions, questions, and criticism from other scientists. Peer review can also help determine if data were reported accurately and honestly. Based on their peers' responses, the scientists who submitted their work for review can then reevaluate how to best interpret their data.

Section 1.4 Assessment

Reviewing Concepts

1. How do scientists organize data?
2. How can scientists communicate experimental results?
3. What does a given point represent on a line graph?
4. The density of copper is 8.92 g/cm^3. If you plotted the mass of copper in grams versus the volume in cubic centimeters, what would the slope of the line be?

Critical Thinking

5. **Comparing and Contrasting** When would you choose a line graph to present data? When would you choose a bar graph?
6. **Using Tables and Graphs** Count the number of students in your class with blue eyes, brown eyes, and green eyes. Display these data in a table and bar graph.

Connecting Concepts

Scientific Methods Reread the description of scientific methods in Section 1.2. Then write a paragraph explaining which steps in a scientific method might require data to be organized. (*Hint:* You might use information diagrammed in Figure 7.)